




Wheelchair Cushions- The Science behind seating

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Important characteristics of wheelchair cushions

- 
- **Mechanical Properties**
 - Load deflection
 - Recovery
 - Impact Damping
 - Loaded contour depth
 - Frictional properties
 - **Load redistribution**
 - Envelopment
 - Off-loading and redirection
 - Interface Pressure Distribution
 - **Heat & Water Vapor Dissipation**

Cushion Materials:

Material combinations dominate

- Foam/flexible matrix: GeoMatt, Supracore, Fundamental
- Foam & Elastomer/gel: Southwest Technologies, Action
- Foam & Viscoelastic Foam:Maxus, Infinity, Ultimate
- Foam & Viscous Fluid: Jay, Cloud, Skil-Care
- Air: Roho, Star, BBD
- Air & Foam: Varilite, Nexus






Mechanical Properties

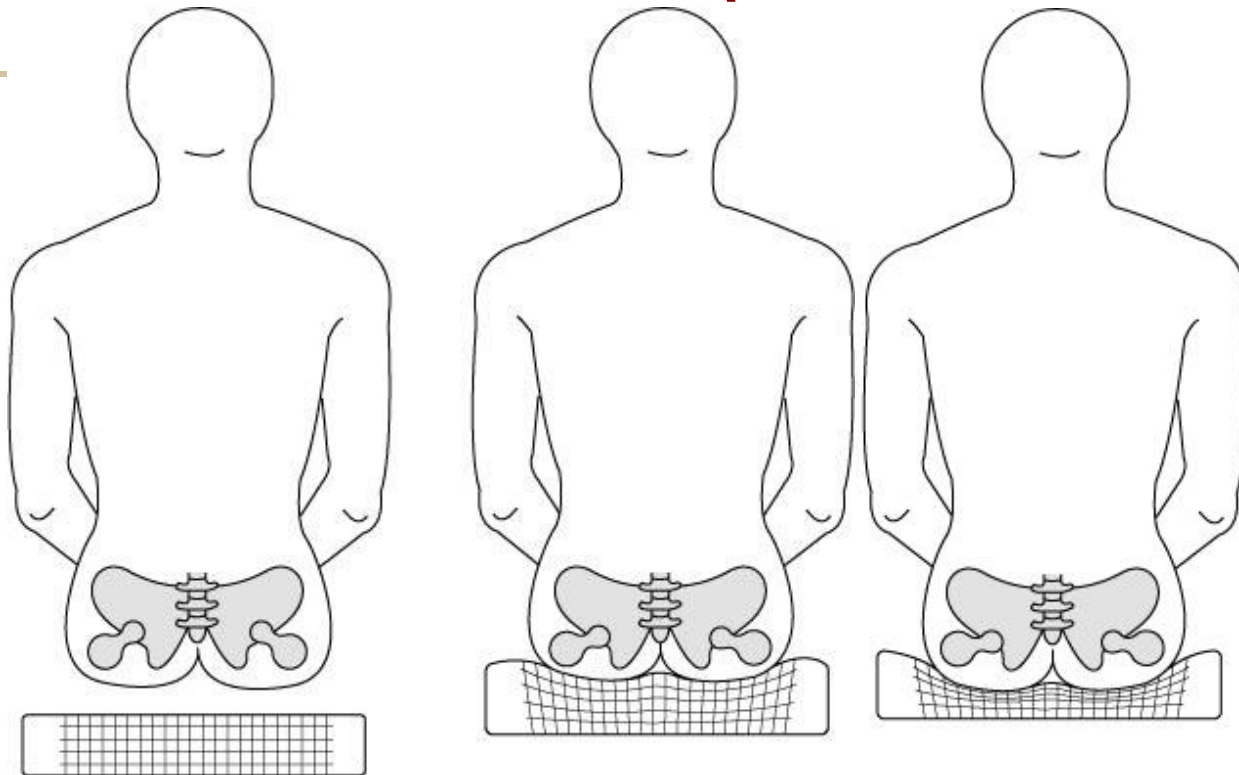
- Different materials accommodate body load in different manners
 - foam and air: compression
 - gel and viscous fluid: displacement
 - cover (bladder and/or fabric): tension

Mechanical Properties:

Load deflection

- 
- Stiffness is a measure of deflection under a given load
 - Foam: Indentation Force Deflection
 - Elastomers and gel: durometer
 - Viscous Fluid: viscosity & bladder volume
 - Air: Internal air pressure and bladder stiffness
 - The trick is finding the proper stiffness
 - Too stiff → high loads 2° to poor deflection
 - Too soft → bottoming-out 2° to over-deflection
 - Material combinations used to accommodate various needs

Foam: compression



Sitting on foam induces compression bending, tension of material

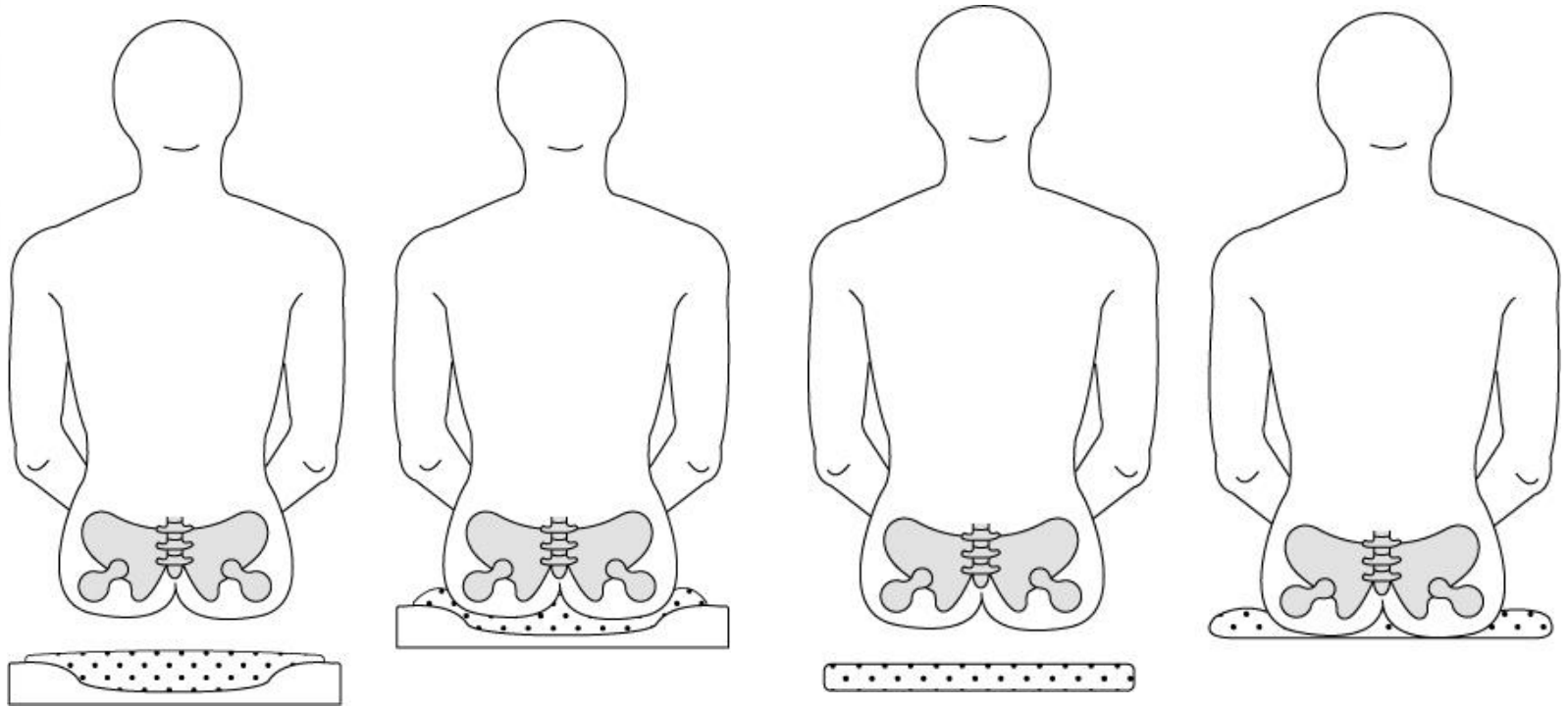
Segmented foam is functionally softer- reduced surface tension

(foam does not like to stretch)

Trick is to find foam that compresses just enough (40-60 IFD is typical for 3")

Foam gets softer over time (fatigue)- look for tears, compression set

Viscous Fluid

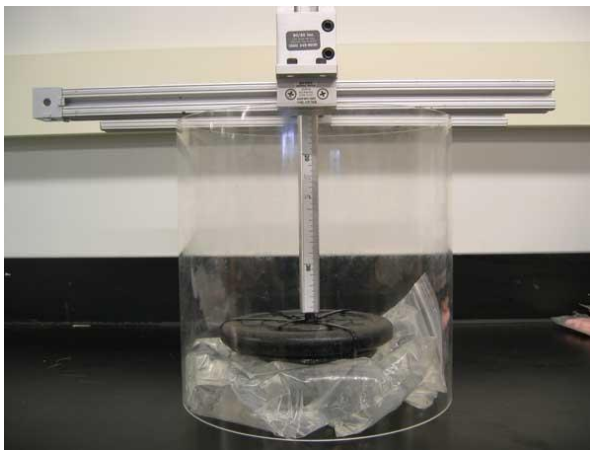


Requires proper base, bladder and volume of fluid
Best viscous fluid cushions are combination cushions
(bladder alone would not be good)
Concept: allow fluid to flow and contain buttocks

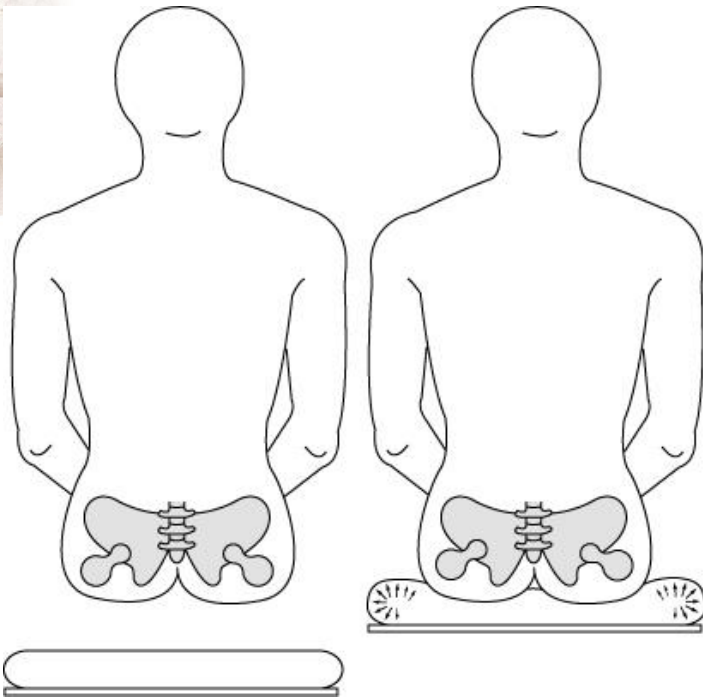
Viscous Fluid: volume not viscosity matters

	Beveled Indentor	12 lb Bowling Ball
High viscosity Mineral Oil		
200 ml x 10 bags	2.3	2.8
150 ml x 10 bags	1.8	1.7
WATER		
200 ml x 10 bags	2.4	3
150 ml x 10 bags	1.6	1.8

This mineral oil was 75x more viscous than water



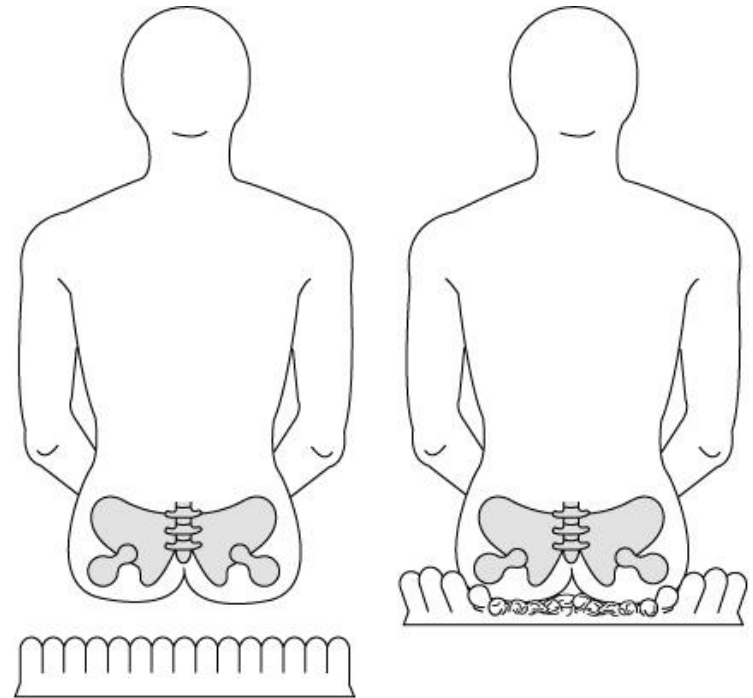
Air: container and volume matters



Single bladder system

Single air pressure

Envelopment highly bladder dependent



Multi-segmented bladders

Single air pressure

Segment collapse and expansion

All adjustable cushions require assessment

Over-inflation risk



Load redistribution

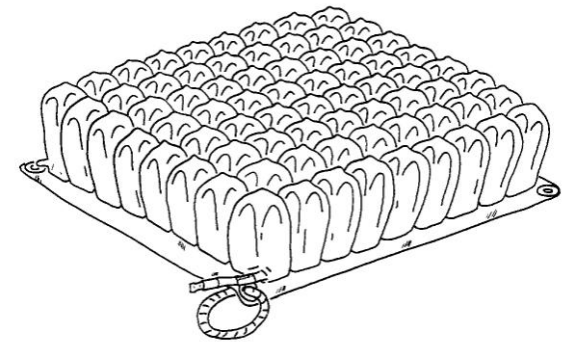
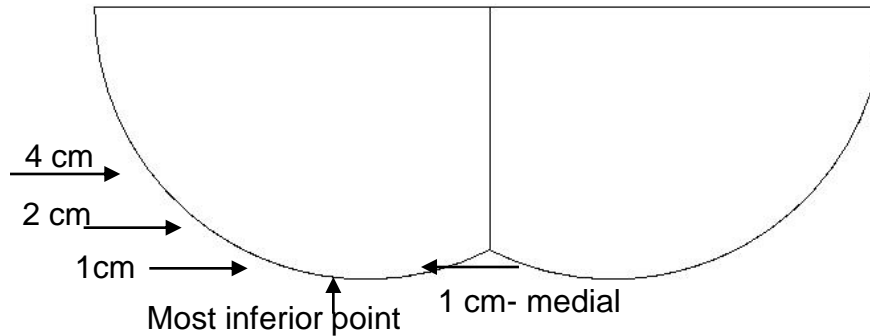
- The ability of a cushion to manage loads on the buttock tissues impacts tissue health and comfort
- Techniques used include:
 - Envelopment
 - Redirection of forces (including off-loading)

Envelopment

- Capability of a support surface in deforming around and encompassing the contour of the human body.
- An enveloping cushion should have the ability to encompass and equalize pressure about irregularities in contour due to buttock shape, objects in pockets, clothing, etc.



Envelopment & how we measure it



Envelopment measures

$$pressureParity = \frac{(P_{IT} - P_{40})}{(P_{IT} + P_{40})}$$

% envelopment =
 $1 - [\text{abs}(\text{pressureParity})]$

	Parity	Envelopment
viscous fluid & foam	-0.13	87%
foam with ischial cutout	-0.90	10%
viscous fluid & foam	0.38	62%
Reference flat HR45	0.93	7%
Reference flat HR70 foam	1.00	0%
segmented air	0.38	62%
viscoelastic foam	0.77	23%

← Good envelopment & IT loading < loading @4 cm

← Off-loading IT's

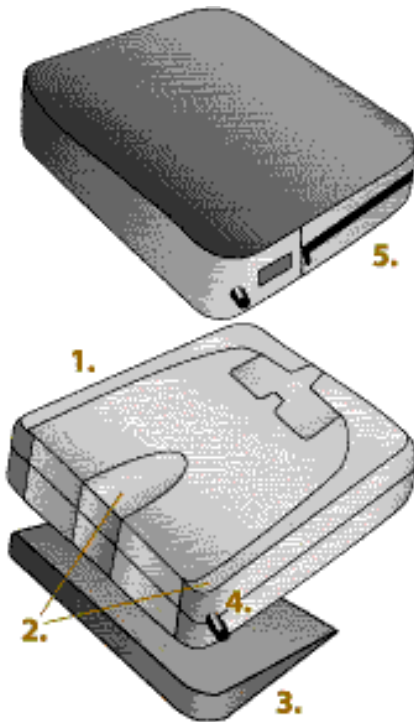
} Minimal or no contact at 4 cm



Redirection of forces & off-loading

- Choosing where to apply loads on the body is commonly used in prosthetics and orthotics
- Several cushion designs use this approach to reduce ischial loading
 - Isch-Dish; Ride Designs
 - Contoured systems
 - Any system with ‘reliefs’ in a region

Designs meant to redirect forces

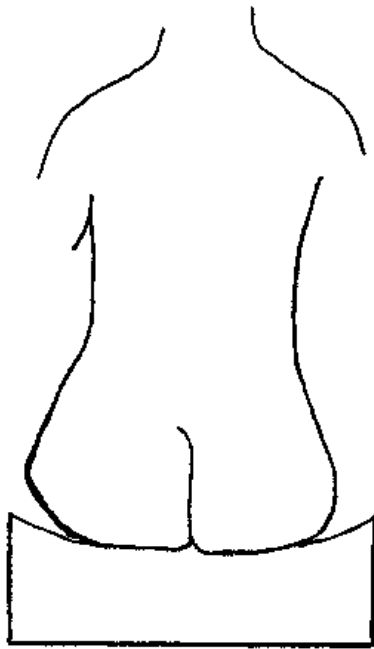


Poor redistribution of forces

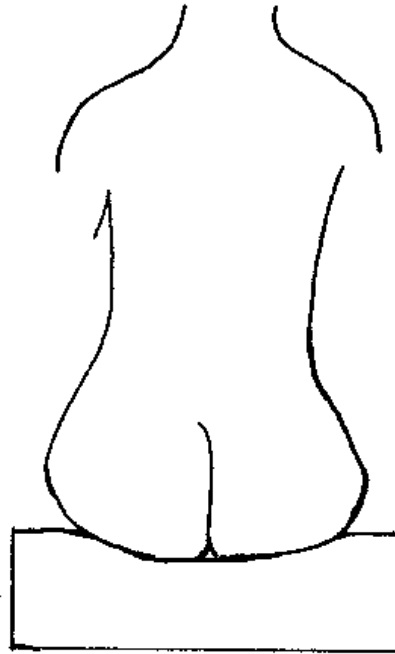
Poor envelopment

Poor redirection

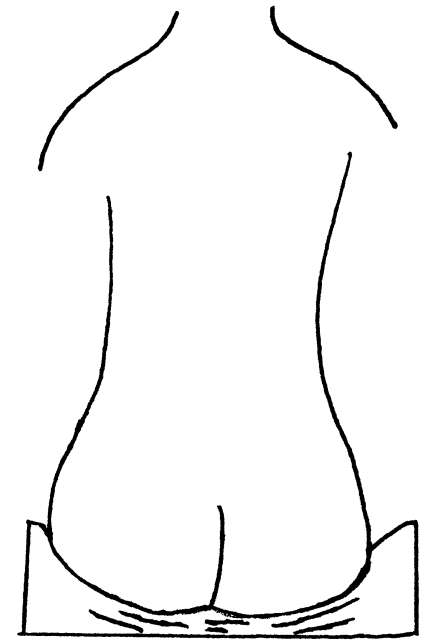
- Hammocking caused by a taut, non-stretch cover



- Poor envelopment due to high cushion stiffness

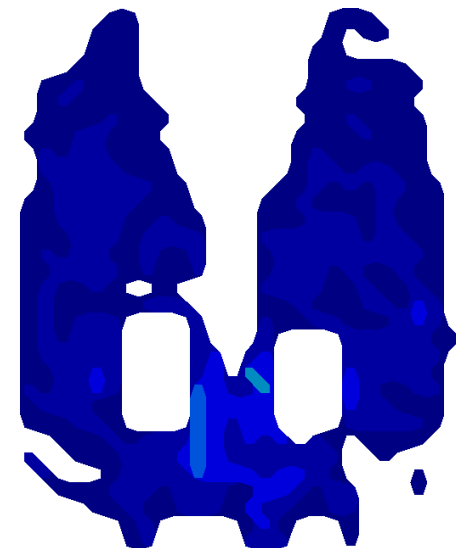
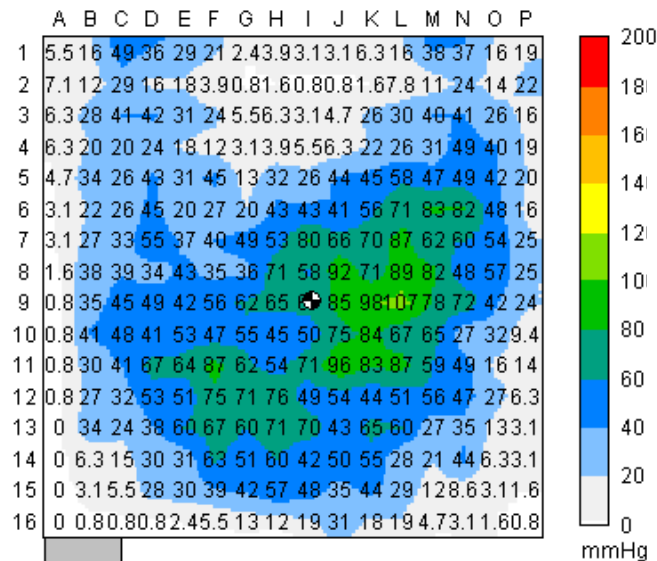
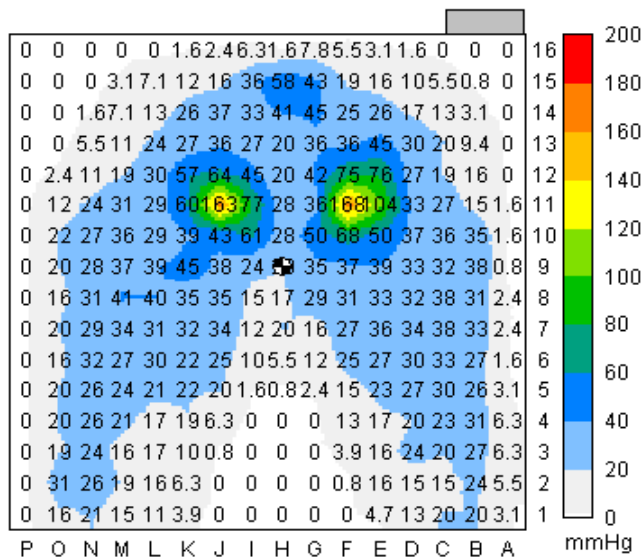


Bottomed-out condition caused by too soft a cushion



Interface pressure distribution

- Interpretation is the hardest part
- MUST match anatomy to pressure via palpation
- IP should reflect intended cushion design
- Best use: to r/o cushions rather than to prescribe them

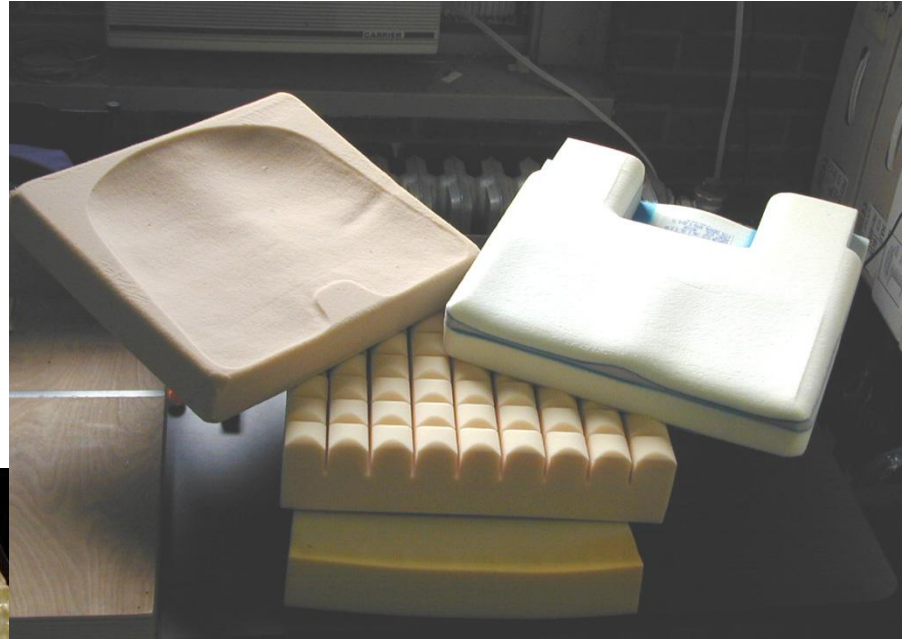


Horizontal Stiffness/Sliding Resistance



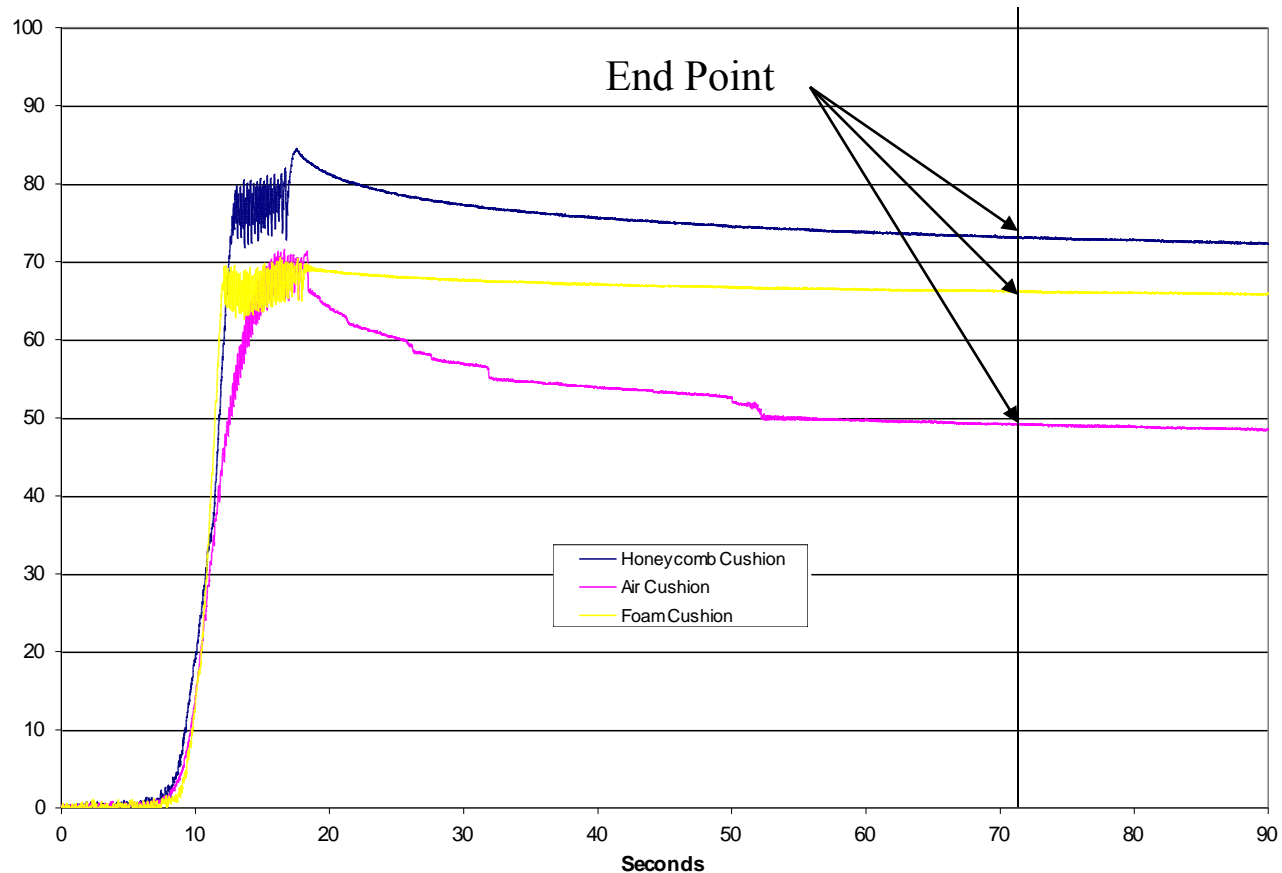
Horizontal Stiffness

High Horizontal Stiffness

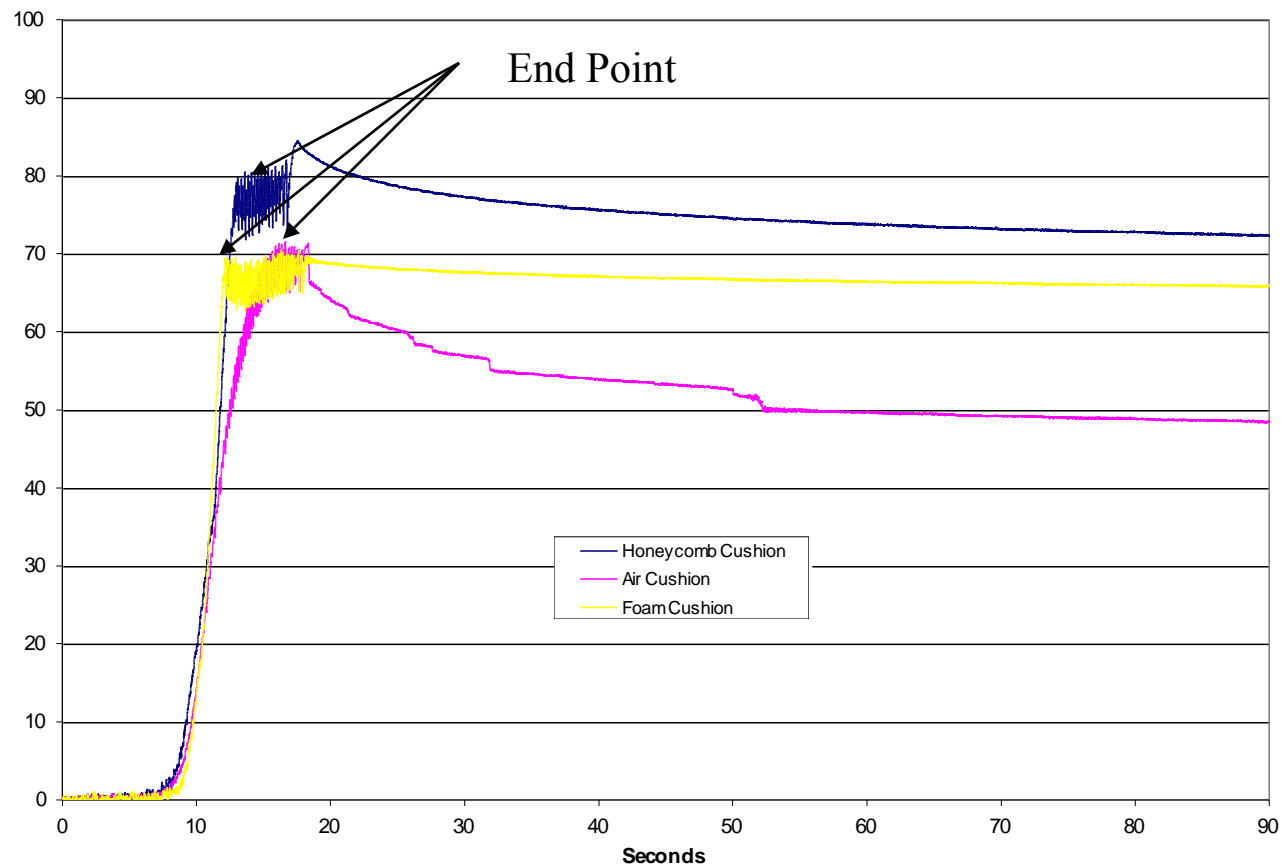


Low Horizontal Stiffness

Horizontal Stiffness Data



Sliding Resistance Sample Data

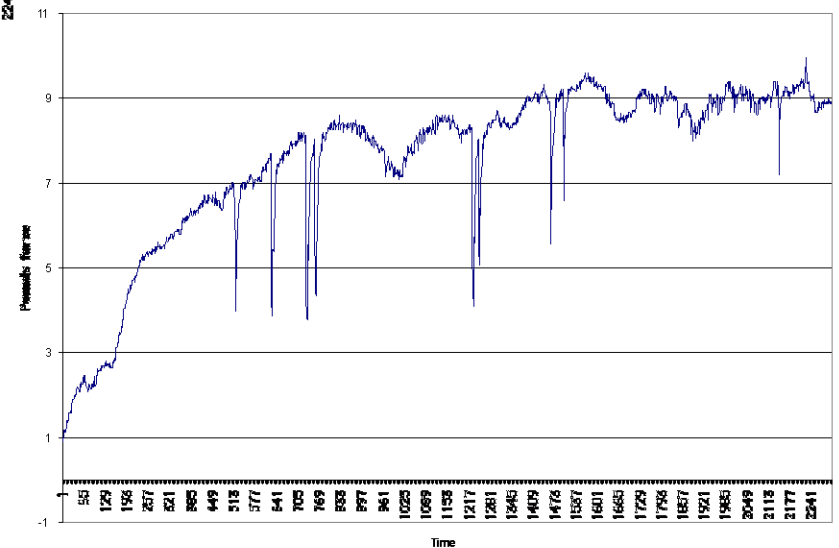
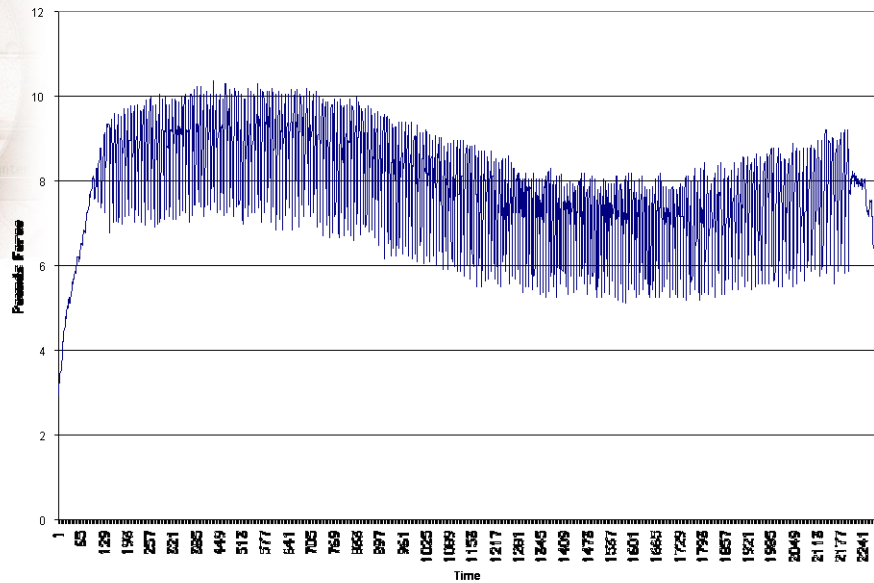


What Does it Mean To the Tissue

- Repositioning or daily activity applies a lateral load to the tissue
- This is required for a sense of “Functional Stability”
- If the cushion does not accommodate the tissue over time potentially undesirable loading may occur



Friction Test Data of Interest





Friction Lessons Learned

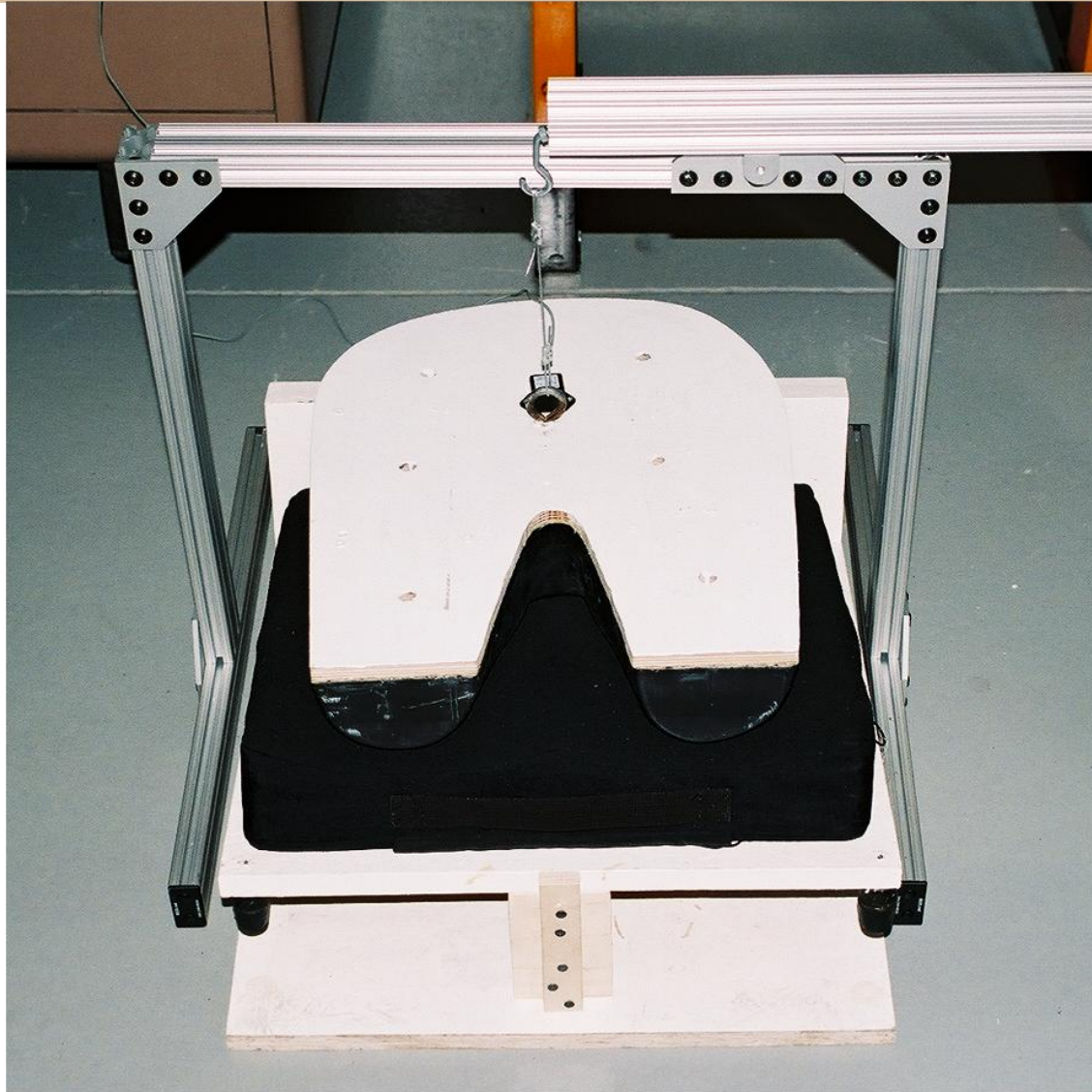
- Static friction represents the load to the skin that is translated into shear
- Dynamic friction is variable and represents dragging the tissue over the cushion
- Friction contributes to shear separation of tissue layers and skin damage
- Heat from friction from repetitive motion damages skin
- Friction may not be “Bad” or “Good”, it is required to stay on a cushion

Friction and Shear can not be Separated

- The pain caused by peanut butter under your tongue is shear
- Shear introduces forces that separate tissue layers
- Shear introduces torsion, reducing blood vessels resistance to collapse



Impact Dampening



Impact Dampening

Low Impact Transmission



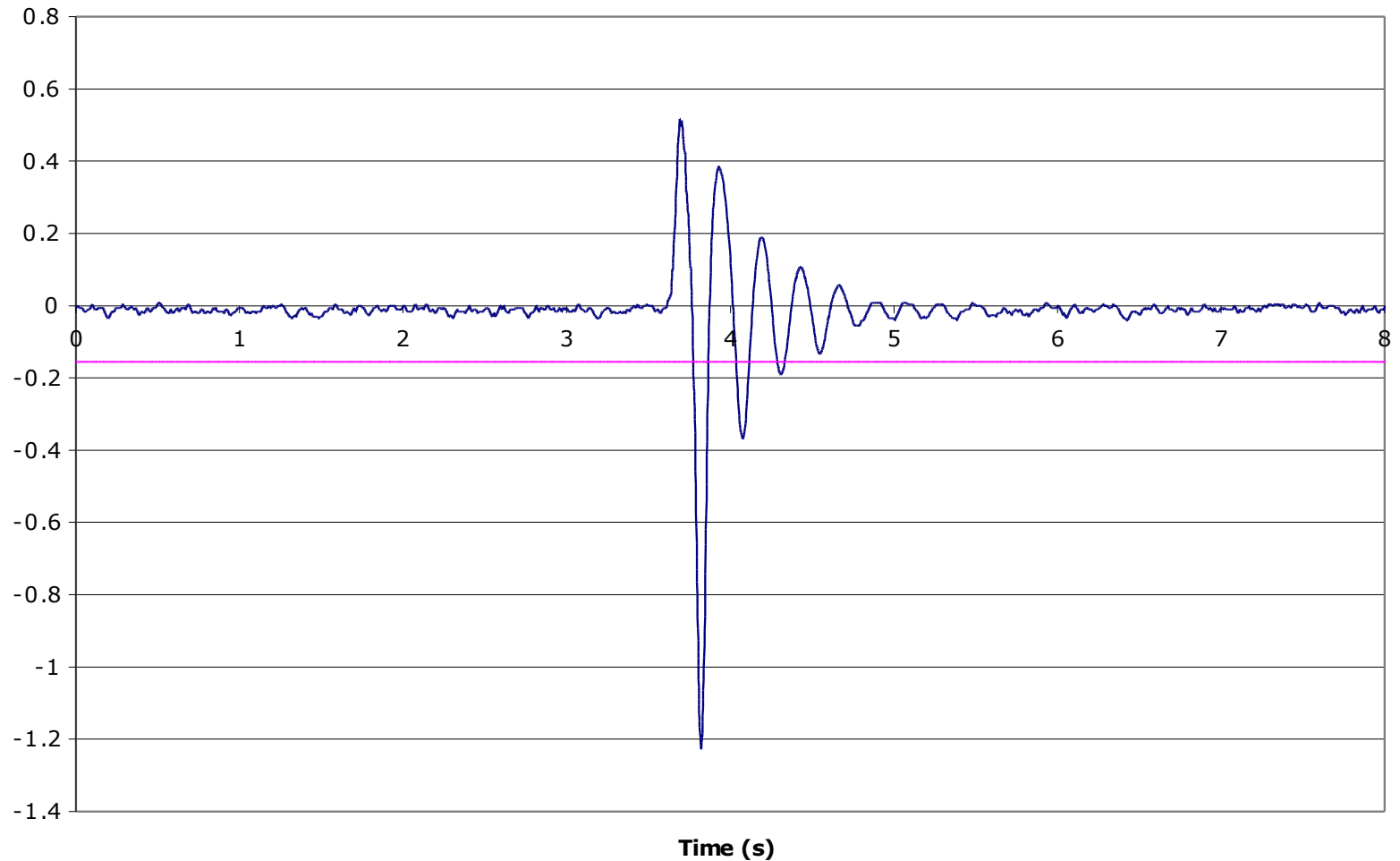
Higher Impact Transmission



Impact Dampening Test Results 45 ILD Foam



Impact Dampening G's vs Time



Impact Dampening Reported Values



Res1: Mean number of Rebounds greater than 10% of Peak Positive Rebound Acceleration	Res2: Mean of the Peak Rebound (positive) Acceleration relative to the Baseline (negative) Acceleration (Gs)	Res3: Ratio of the of the second rebound relative to the first rebound accelerations (%)
2.67	1.2	45.83%

Is Heat a Problem In Seating?

- Heat is a major non-pressure risk factor for pressure ulcers (Kokate 1995)
- Superficial ulcerations constitute 58% of all pressure ulcers (Barbenel et. al., 1977)
- Current Study is aimed at measuring the complicating nature of heat, or the protective nature of cooling





Heat's Effect on Skin

- Heat related metabolic stress in skin increases 43% from 28°C to 34°C (Arrhenius 1889)
- At 28° sudor appears as the body tries to cool itself (Brenngelmann and Brown, 1965)

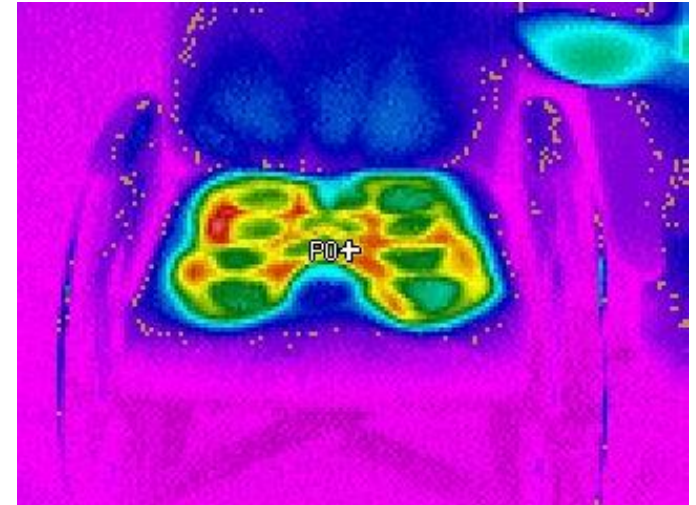
Heated Buttock



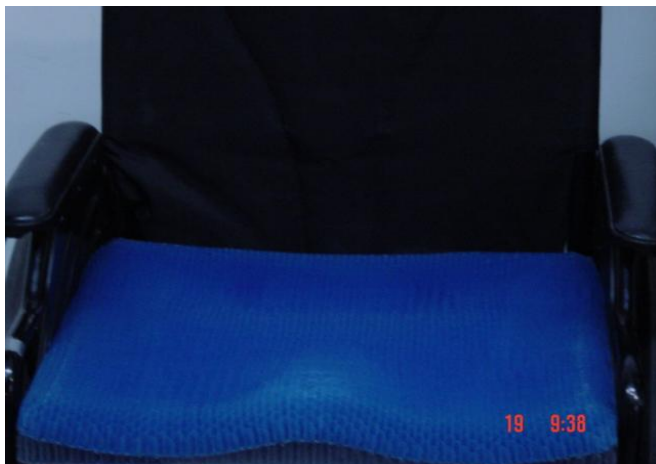
Results of Heated Indenter Tests



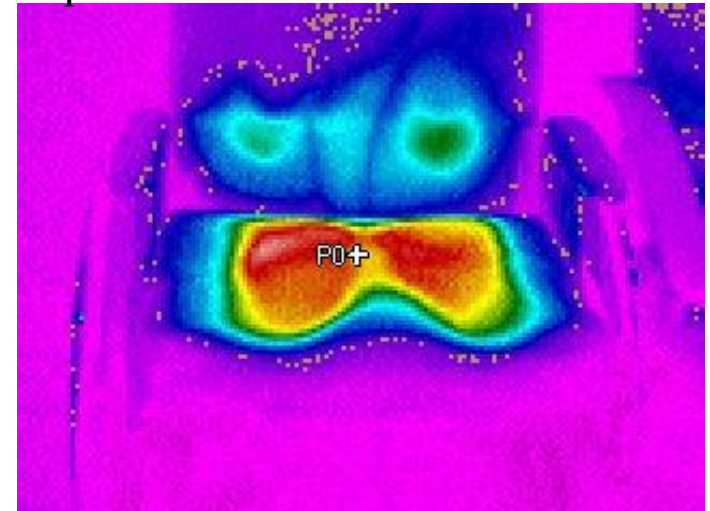
Cushion 1



IR photos after 1 hour simulated use



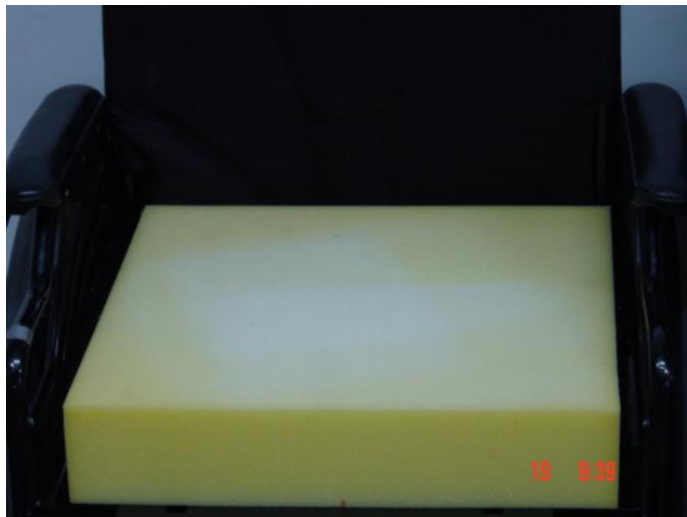
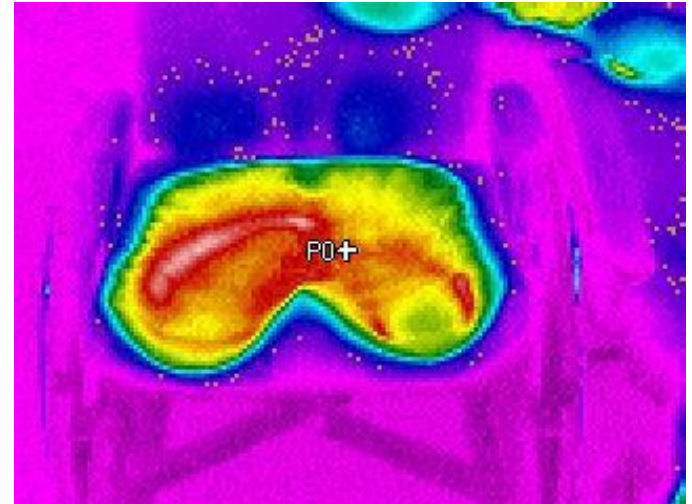
Cushion 2



Results of Heated Indenter Tests

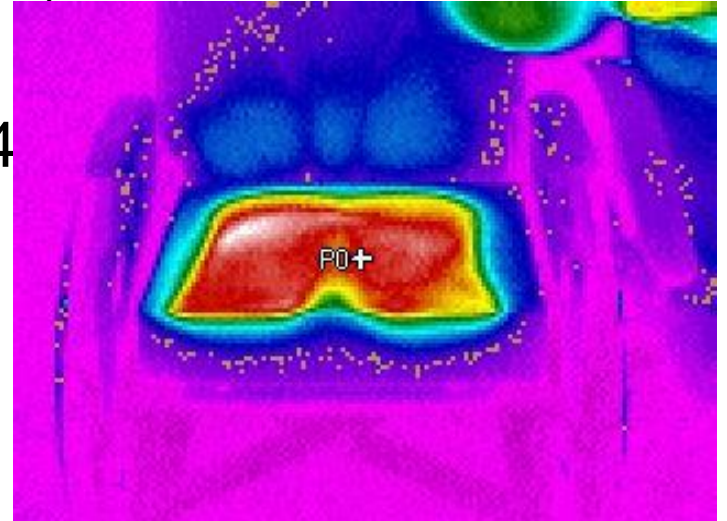


Cushion 3



Cushion 4

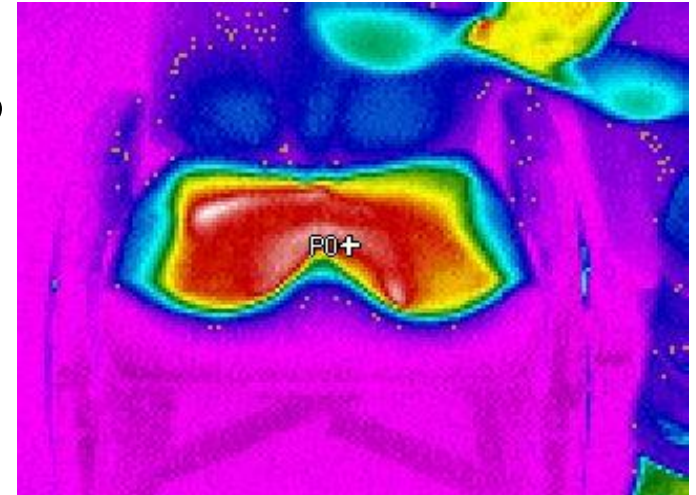
IR photos after 1 hour simulated use



Results of Heated Indenter Tests



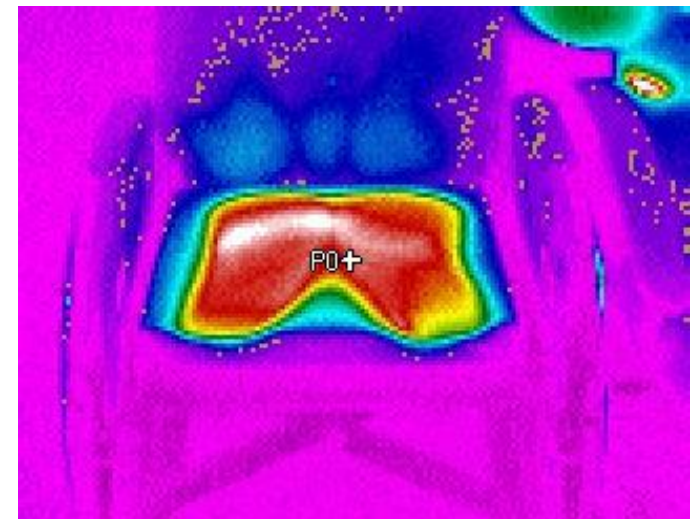
Cushion 5



IR photos after 1 hour simulated use



Cushion 6



Low Thermal Mass



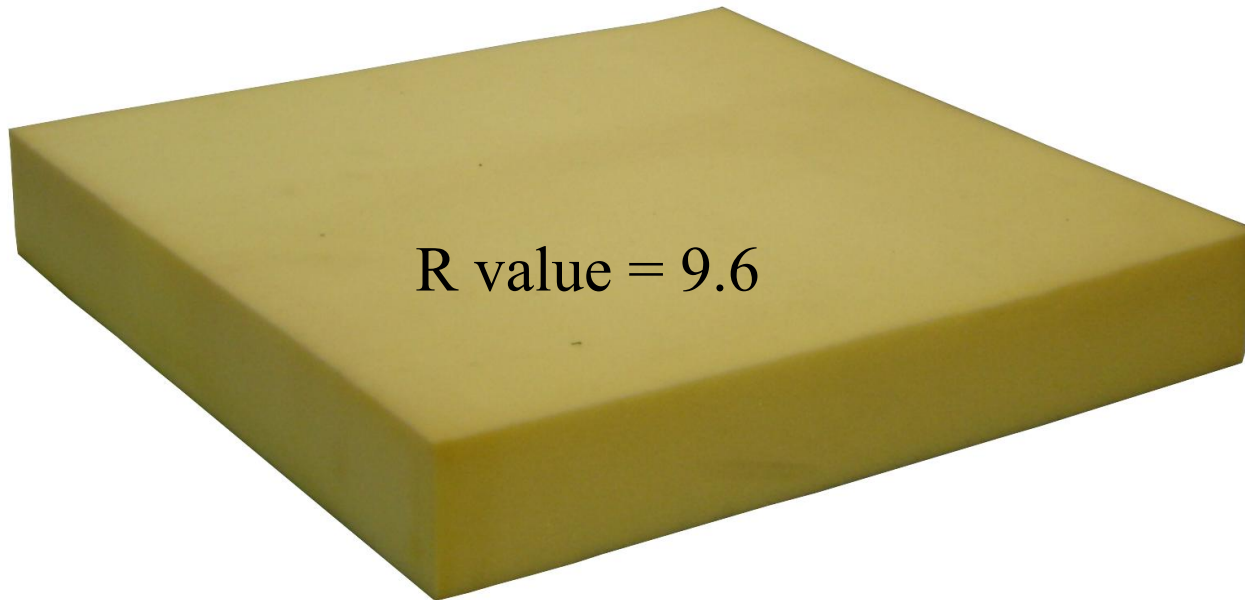
Combination Thermal Mass



Breathing Channels



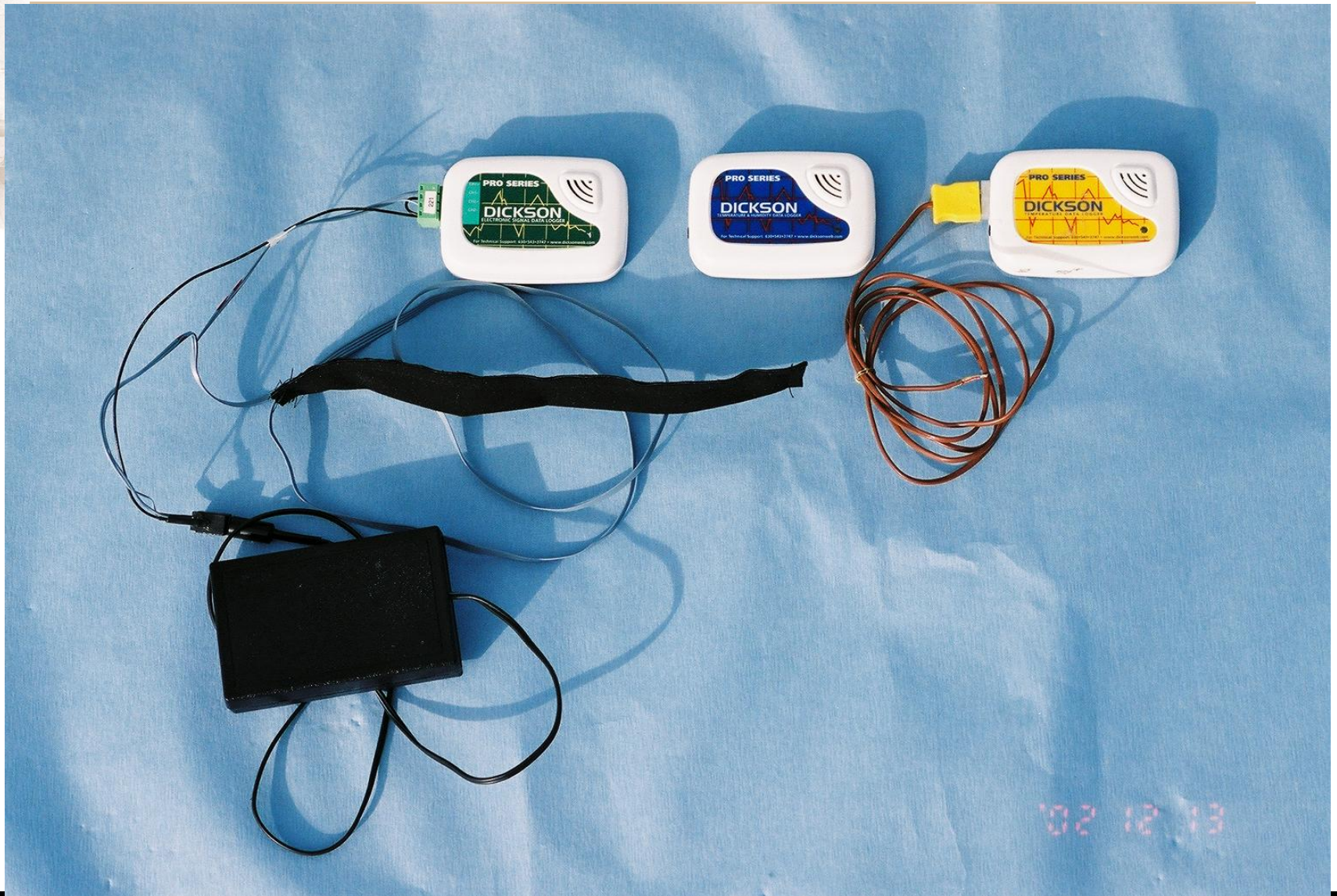
Heat: Traditional Materials (Foams) are Insulators



Sweat Condensation on Stone Sitting Surface



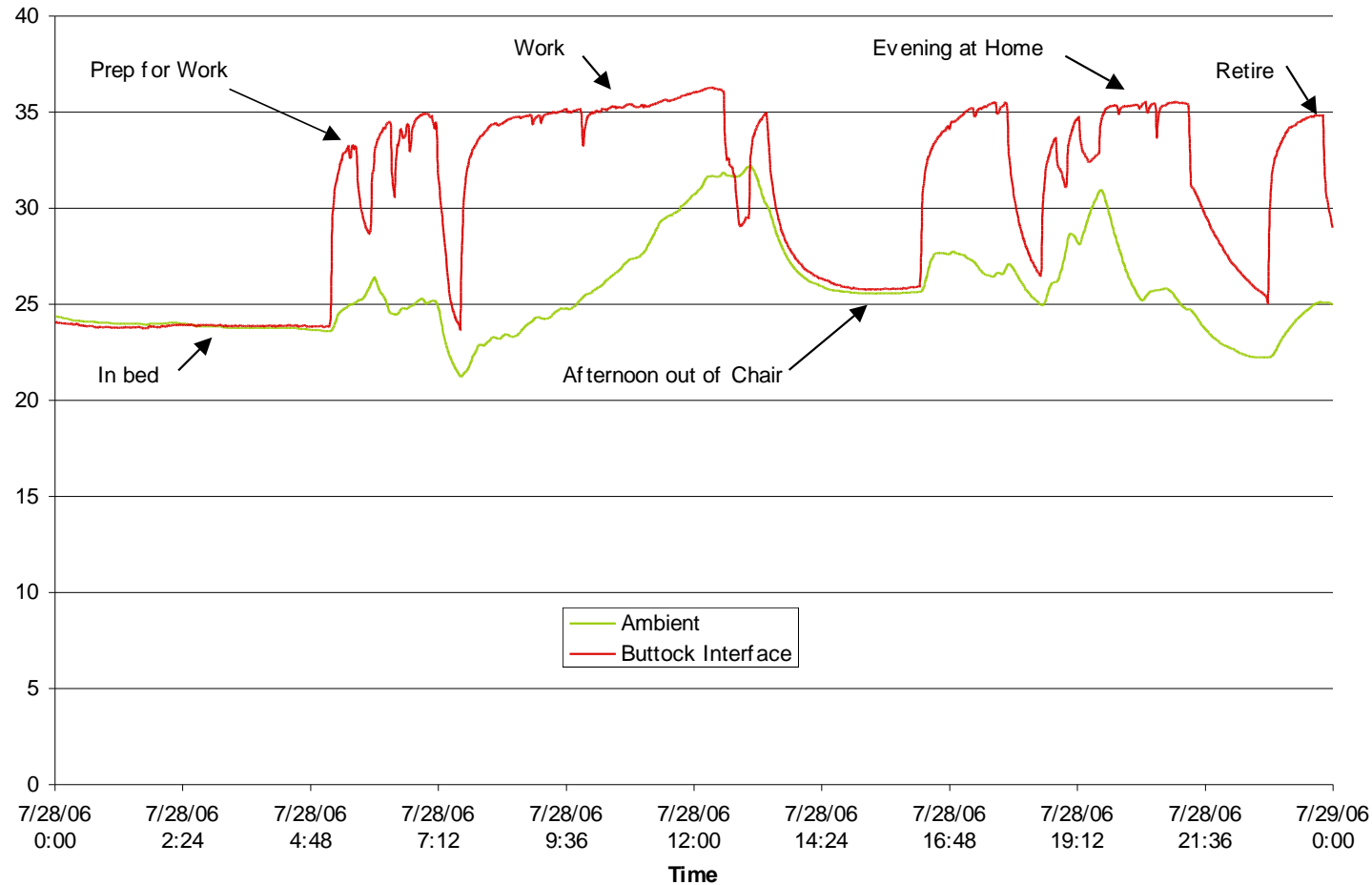
Heat and Humidity Data Acquisition



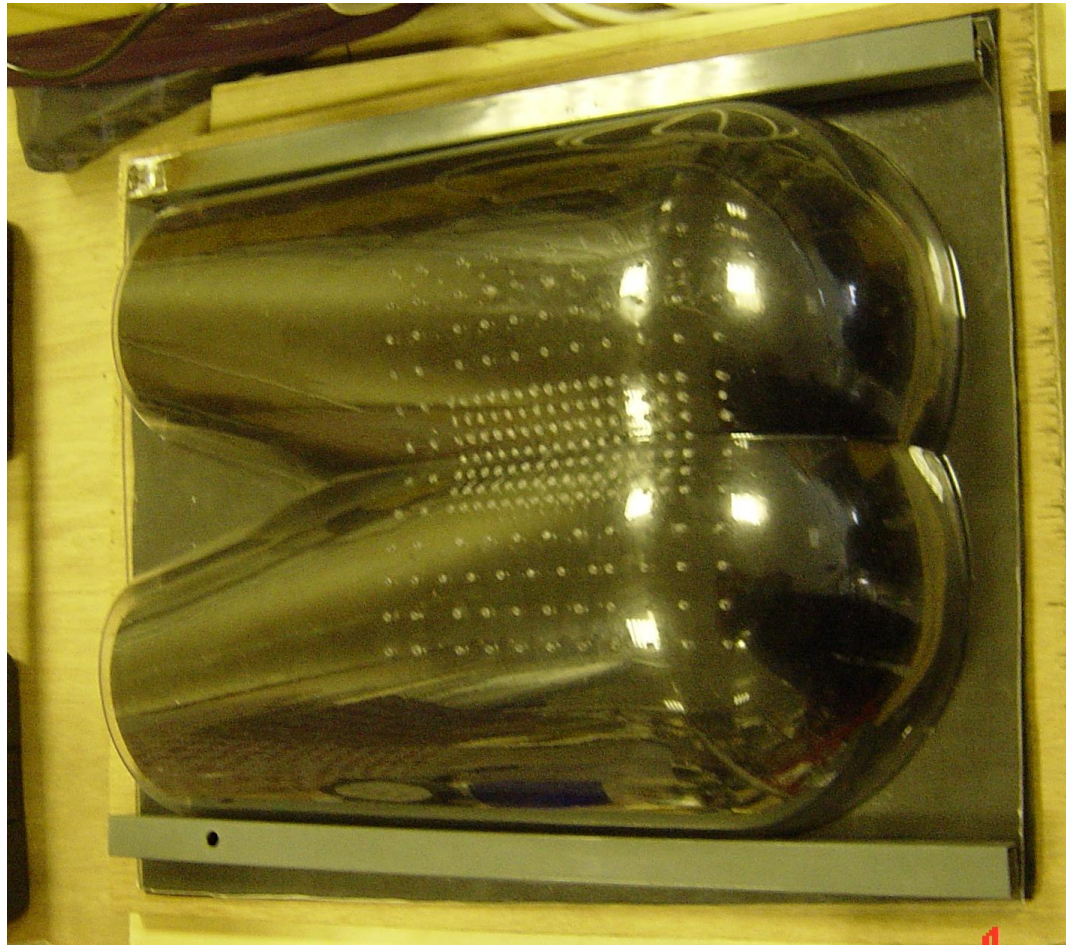
Graphs of Temp over 24 Hrs



Male #1 Summer Cushion Temperature 07/27/0



Heat and Water Vapor Indenter






Moisture Lessons Learned

- Sudor, (sweating)
 - Begins at 28°C skin surface temperature
- Moisture changes the mechanical properties of skin
 - Decreases resistance to deformation, abrasion
 - Increases friction
 - Try the fingers on your arm test...



Translating
technical/mechanical property
detail to clinical practice
everyday decisions...

What does all this mean when selecting an appropriate wheelchair cushion?

- 
- What Matters?
 - Posture - Stability
 - Skin Integrity
 - Function



Stiffness

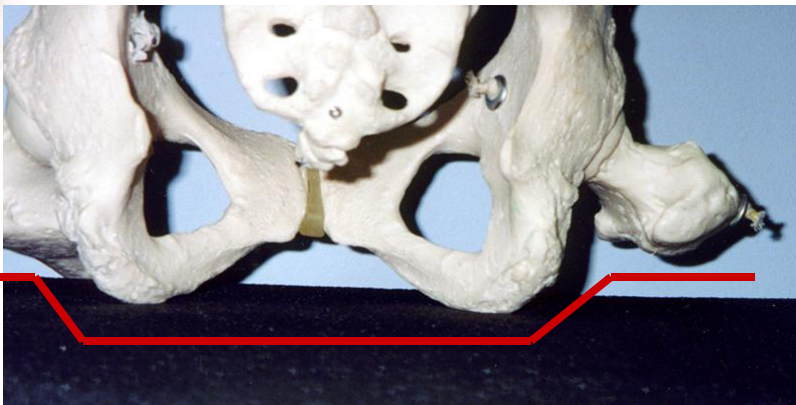
Too stiff → high loads 2^o to poor deflection

Clients buttocks cannot “sink in” to the cushion

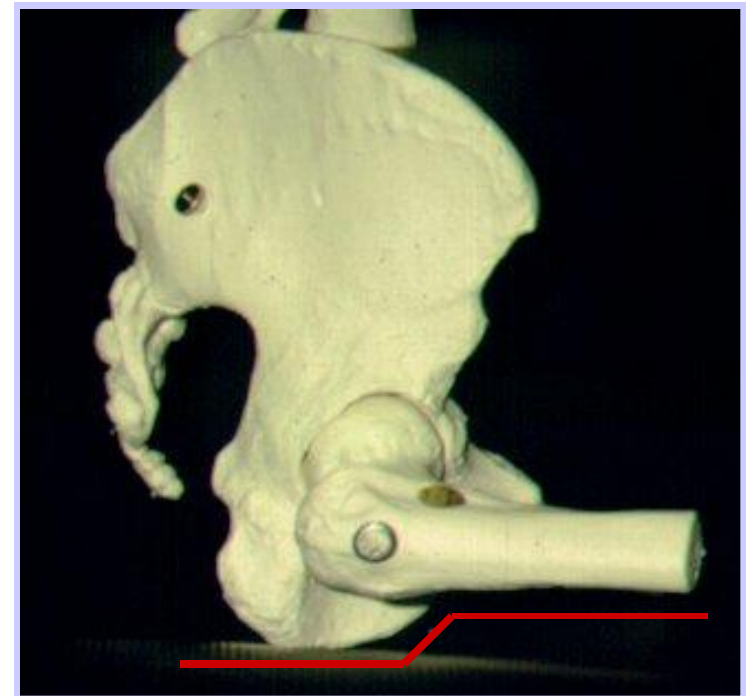
- Sitting on top instead of “in” the cushion
- **Skin Integrity** – Higher peak pressures
- **Postural Stability** – Increased or Decreased ?
 - Surface contact area – less contouring – could mean less fwd/rearward stability..
 - Lateral stability however could be better



Forward -
rearward stability



Lateral Stability





Stiffness – Too stiff...


- **Function**- Increased or Decreased?
 - Could mean easier transfers?
 - Could mean decreased distal function due to decreased core stability



Clinical Examples

- Cushion with high density foam under a child
 - sitting on “top” of it
 - May need to consider a medium or softer density or layering
- Cushion that has fluid with too much volume or too viscous – it does not conform well to the buttocks - client is sitting on top – not “in”
- Cushion that has too high internal air pressure
 - again, client sits on top – not “in”

Stiffness

- 
- Too soft → bottoming-out 2° to over-deflection
 - **Skin Integrity** – Higher peak pressures
 - **Postural Stability** – Decreased ?
 - Surface contact area – less contouring – could mean less fwd/rearward and lateral stability..
 - **Function**- Increased or Decreased?

Clinical Examples

- Cushion with soft or medium density foam under a heavier person— flattens and bottoms out
- Cushion with too low air pressure – under-inflated – client bottoms out
- Cushion with fluid that is too viscous – too runny in a container not correctly fitted to the client- client bottoms out



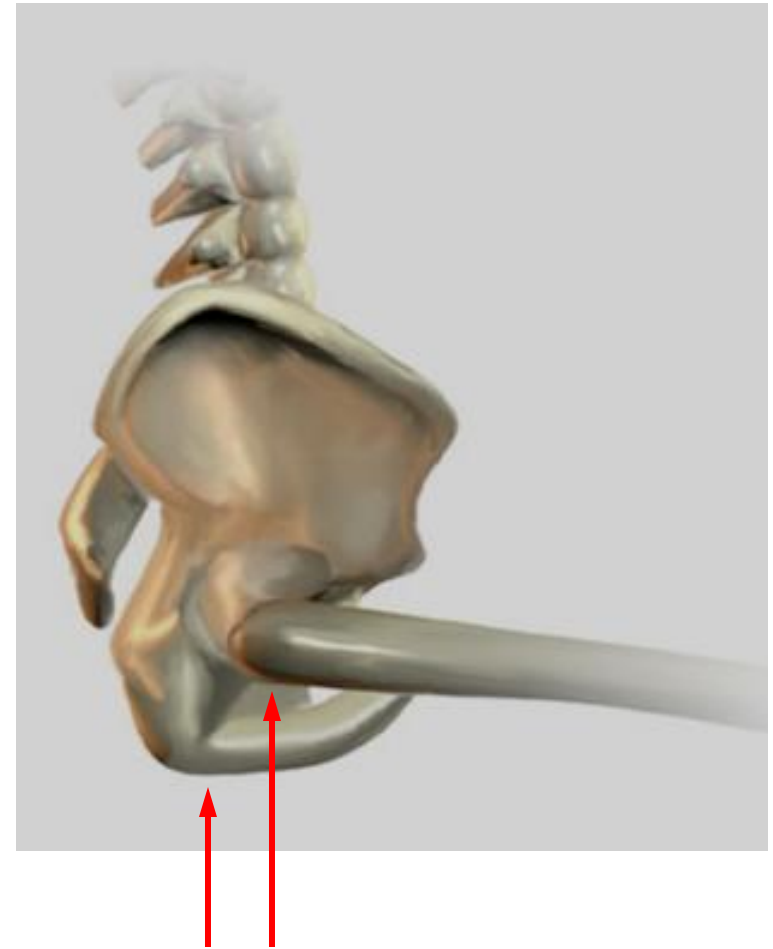
Load redistribution

- The ability of a cushion to manage loads on the buttock tissues
 - Envelopment
 - Redirection of forces (including off-loading)
 - Interface Pressure Distribution

How well does the cushion conform?

■ Good Envelopment

- The buttocks are immersed with good conformation to unique shapes
- Life is “Good”
- Remember the ischials in a bony person need to be able to immerse approx 2” without bottoming out



Approx. 2"



Good Envelopment

- **Skin Integrity** – Overall lower pressures
- **Postural Stability** – Increased surface contact area — could mean more stability..
- **Function**- Increased or Decreased?
 - Can the client carry out their desired functional activities?

How much does this matter when

...Anything that interferes with the conformation is placed over top of the conforming material?

- Chuck pads
- Slings
- Diapers
- The list goes on.....!!!!





Redirection of forces

- Choosing where to apply loads on the body
- Generally we try to
 - load the areas tolerant of load
e.g. the posterior thigh, feet and thorax
 - redirect load from areas less tolerant,
e.g. the ischials, sacrum

The BIG Questions –

Can the client tolerate load for long periods of time on these areas?

Does the client **consistently** get put into this shape that has been created for them

If they need to move – can they?



Heat and Water Vapor Dissipation

- Is the cushion material an insulator or conductor of heat?
- What are the variables? – clothing – climate- etc
- Is the cushion moisture resistant with and without the cover?
- Is the moisture trapped around the skin surface?
- Incontinent covers – pads – diapers?

Questions..



Thanks for Your Attention

